RESEARCH HIGHLIGHTS

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VENTILATION SYSTEMS FOR MULTI-UNIT RESIDENTIAL BUILDINGS: PERFORMANCE REQUIREMENTS AND ALTERNATIVE APPROACHES

Introduction

Multi-unit residential buildings (MURBs) represent a significant, and growing, proportion of housing in Canada. While there have been many advances in building envelope, life safety, heating and air-conditioning systems, ventilation strategies have not changed significantly over the past three decades. Research by CMHC and others has shown that conventional corridor air supply and bathroom-kitchen exhaust systems do not, and cannot, ventilate individual apartments. Furthermore, conventional strategies consume significant a significant amount of energy, can be noisy, consume internal floor area and serve as possible conduits for pests and smoke during fire emergencies. While this has been problematic in the past, it can be expected to become a greater issue as buildings are being constructed with an increasing emphasis on the continuity of air barrier systems as a way of addressing energy conservation, envelope durability and occupant comfort concerns.

In recognition of the lack of progress in the evolution of ventilation systems for MURBs, CMHC initiated a research project to identify the common failings of conventional approaches and to develop design parameters that could be used to engineer better approaches.

Research Program

The purpose of this project was to develop performance requirements and alternative approaches for ventilation systems that address problems with conventional systems and better meet the needs of the owners and occupants of MURBs. The project objectives were:

1. To identify problems and issues with conventional ventilation systems that must be addressed by alternative ventilation strategies.
2. To review existing ventilation standards and develop recommendations for and a method of calculating optimal ventilation rates for individual apartments.
3. To develop performance parameters to evaluate the performance of alternative ventilation systems.
4. To develop recommendations and specifications for effective and efficient ventilation strategies for individual apartments, and compare the cost and performance of these improved systems against conventional systems.

The scope of this project was limited to multi-family buildings of any size with suite entry from common interior corridors. These buildings were assumed to have building envelope constructions equal to or better than required by current building codes.

Research Findings

Problems and Issues with Conventional Systems

A literature review was conducted to identify problems and issues that must be addressed by alternative ventilation systems. Typical systems in apartment buildings are generally designed with the intent of limiting the migration of contaminants between suites and into the corridors. They are not specifically intended to provide ventilation for indoor air quality within suites. Several research studies that were reviewed showed that much of the air delivered by corridor systems bypasses apartments, exiting the building via shafts, stairwells and other leakage points. Infiltration through exterior walls

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and the use of operable windows is often relied upon to ventilate apartments. As infiltration in high-rise buildings is a complex function of stack/wind and mechanical system effects, ventilation provided by infiltration alone can be difficult to predict and control. Consequently, apartments can often be over- or under-ventilated, which in turn can compromise occupant health and comfort. Excessive space conditioning energy use and damage to building envelope can also occur under such conditions.

Ventilation systems are the subject of many occupant complaints. Noise from central ventilation systems can transmit to apartments located close to the system and also can transfers through system ductwork to all suites. Undesirable noise created by small in-suite bathroom fans and kitchen rangehoods can prevent their use. Occupant also express frustration in not having control over their ventilation systems to respond to changing indoor environmental conditions. The movement of odours, particularly cooking odours and tobacco smoke, is the most common indoor air quality-related complaint that conventional systems seem incapable of addressing. Most importantly, conventional ventilation systems can compromise the integrity of fire and smoke control because they are dependent on a high level of interconnectivity between individual apartments and public areas.

Recommendations for Ventilation Rates

An evaluation of the various codes and standards governing the ventilation capacities for apartments in multi-unit residential apartment buildings in Canada was completed. Based on a review of literature, it was found that the ventilation system airflow rates required for any given apartment, as well as the portion of ventilation expected to be provided by infiltration, can vary significantly depending on the standards or codes referenced. An examination of ventilation rates required to dilute contaminants, such as odour, TVOC emissions from new carpet, and CO, NO_2 and fine particulate emissions from gas ovens, found them to be too high for practical application in residential environments. Balancing the requirements of contaminant dilution, occupant needs, capital and operating costs, ventilation rates based on 7.5 L/s per person were recommended.

Performance Parameters to Evaluate Alternative Ventilation Systems

To evaluate ventilation performance, performance parameters and minimum targets were developed (Table 1).

Table 1

Performance Parameter	Performance Target
Ventilation performance	• continuous ventilation rate of 100% outdoor air based on a rate of 7.5 L/s per person. Two persons are assumed for the first bedroom and one additional person for each additional bedroom • ventilation effectiveness of 1.0 or greater
Capital and operating costs	• nominal increase in capital cost over conventional systems • 10% to 20% reduction in ventilation energy consumed
Maintenance	• all equipment requiring maintenance located in easily accessible locations
Fire/Smoke control	• systems should not undermine the integrity of fire/smoke control systems and partitions • minimize the need for fire dampers required for vertical ducts through floor to floor separation
Noise issues	• sound separations between apartments and common areas should not be undermined • 0.6 sone limit on local intermittent-use fans
Comfort	• no cold drafts from air supply
System issues	• simple to use controls • simple to maintain • slight depressurization of suites (less than 10 Pa)
Owner/designer construction issues	• ventilation system should not take up any more floor area than conventional systems

Alternative Ventilation Strategies

The performance parameters outlined in Table 1 were used to identify four possibilities for alternative approaches to ventilation issues in multi-unit apartment buildings. For all systems, bathroom exhaust is achieved through continuous exhaust only, with no provision for intermittent flow rates. A separate kitchen intermittent exhaust fan often required by building codes, could be provided as an option at additional cost.

System 1: Passive Vents with Suite-Based Mechanical Exhaust

Fresh air is passively drawn from outside into each bedroom and the living room via inlets installed on the exterior walls near the ceiling. Suite exhaust is removed continuously through the bathrooms. Corridor ventilation is provided separately.

Benefits	• least costly system (incremental cost = $700 per suite) • improved supply outdoor ventilation air over conventional system • low maintenance • little change from current design and construction methods
Drawbacks	• ventilation performance can be affected by wind and stack effects • no tempering of air supply possible, potential occupant discomfort • requires compartmentalization of suites to be effective
Application	• condos or rental suites in temperate locations such as the lower mainland of British Columbia

System 2: Balanced Individual Suite with HRV units

A heat recovery unit (HRV) in each suite delivers fresh outdoor air continuously. The fan-forced supply is ducted to all bedrooms and the living room and discharged near the ceiling level. A separate exhaust fan in the HRV unit extracts an equivalent continuous flow rate from the bathroom(s). Corridor ventilation is provided separately.

Benefits	• excellent ventilation performance when combined with airtight suite design • least affected by wind and stack effects • reduces space requirements for vertical corridor ventilation risers
Drawbacks	• expensive initial capital cost • greater maintenance in terms of time and costs • operation and training of occupants required • interior space required, two external envelope penetrations required per suite
Application	• condos where each suite is responsible for own maintenance • could be used in rental housing if HRV units are located adjacent to hallways with access panels for maintenance

System 3: Balanced Floor-by-Floor System with Heat Recovery

A floor-by-floor mechanical supply, exhaust, and heat recovery system with constant speed supply and exhaust fans operating at optimum efficiency provides a continuous flow of air to all suites on one floor. Supply air is ducted to all bedrooms and the living room of each suite and is discharged near the ceiling level.

The exhaust fan extracts an equivalent continuous flow rate from the bathroom(s) of each suite. Supply ducts require fire dampers and sound traps where they cross fire-rated partitions between suites and common areas. Corridor ventilation is delivered from the floor supply fan.

Benefits	• good ventilation performance not affected by stack effect when combined with airtight suite design • centralized maintenance and control at each floor
Drawbacks	• ventilation performance could be affected by wind effects • space required on each floor for equipment and overhead ducts in hallways • fire dampers required where ducts cross fire separations
Application	• rental application where centralized control and maintenance desired • could be used in individual condo applications

System 4: Balanced Central System with Heat Recovery

A constant speed rooftop supply fan operating at optimum efficiency provides a continuous flow of air to all suites in the building. Supply air is ducted to all bedrooms and the living room of each suite and discharged near the ceiling level. A constant speed rooftop high-efficiency fan exhausts at a continuous flow rate from the bathroom(s) of all suites.

Exhaust ducts from bathrooms connect to a vertical fire-rated shaft maintained under negative pressure by the central exhaust fan. A rooftop mounted heat recovery unit extracts heat from exhaust air to preheat supply air. Supply ducts require fire dampers and sound traps. Corridor ventilation is delivered by the central supply fan.

Benefits	• good ventilation performance when using constant flow controllers at each floor level to limit negative stack effects (combined with airtight suite design) • lower maintenance • centralized maintenance and control
Drawbacks	• ventilation performance affected by wind effects • no compartmentalization possible • space required for risers and overhead ducts in hallways • system balancing difficult and costly
Application	• rental applications where central control and ease of maintenance desired

These systems represent proposals for possible solutions to ventilation problems in the multi-unit residential buildings. Further testing and assessment is required before the proposed systems can be brought to a marketable phase. All four systems need to be constructed in real buildings and their performance evaluated according to the performance parameters outlined in Table 1 and local building codes. Occupant perceptions of derived comfort, ease of use, maintenance and effectiveness also need to be assessed. Equipment such as sound traps, passive inlet vents, pressure-flow controls, and low-energy/low-capacity fans, must be developed to be low cost, simple to install, and effective.

Other research that has yet to be conducted includes the characterization of stack and wind pressures in multi-unit residential building that can be used to aid in the specification of equipment. More field data is required on the performance of both innovative and conventional systems such as, resultant air change rates, indoor air quality, ventilation effectiveness and energy use throughout all weather conditions, as well as specifications and standards associated with these aspects. Costs and savings associated with the new systems (capital and operational) need to be further investigated. The performance of these new systems has only been considered in the colder months; their operation during the summer months has not yet been explored.

Implications for Housing Industry

As conventional ventilation systems are inadequate in effectively ventilating apartments, superior systems are required to fulfill expectations regarding energy efficiency, occupant health, comfort and safety and building durability. Alternative approaches, which serve to improve ventilation systems and overall building performance, are becoming more available with recent research. However, most of the proposed solutions are still in their early stages of development. Further research in this area of construction needs to be conducted before these alternative systems can be integrated into the mainstream. By supporting the concepts associated with these alternative approaches, the housing industry can help foster the environment necessary to successfully implement these improvements.

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